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PINE PORTAGE GS
EVALUATION OF CONCRETE FOR ALKALI AGGREGATE REACTIVITY

Report No. 89-255-K

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ABSTRACT

The concrete at Pine Portage GS was evaluated for alkali-aggregate reactivity. Concrete cores, drilled from the spillway piers and inspection tunnel wall, were inspected visually and specimens prepared from the cores were examined petrographically and tested in the laboratory. Based on this evaluation, it was concluded that there was no apparent evidence of alkali-aggregate reactivity taking place in the concrete.

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PINE PORTAGE GS
EVALUATION OF CONCRETE FOR
ALKALI-AGGREGATE REACTIVITY

1.0 INTRODUCTION

At Pine Portage GS, squeezing of the stop logs in the spillway gains has caused problems in the operation of the structure. An evaluation of the concrete was undertaken by the Concrete Technology Section, Civil Research Department to determine whether expansive reactions due to alkali-aggregate reactivity were taking place, which could be causing this problem.

The evaluation of the concrete consisted of visual inspection, petrographic examination and laboratory testing of cores drilled from the spillway piers and inspection tunnel wall. The petrographic examination was conducted on polished specimens and thin sections. The laboratory testing included the monitoring of concrete cores stored at 38°C and 100% relative humidity for length change over a one-year period. Specimens were also prepared from the cores and tested using the Split Core test procedure.

The results of the evaluation are summarized in this report.

2.0 VISUAL INSPECTION

In November 1988, concrete cores (85 and 95 mm diameter) were drilled by the Rock Sciences Section, Civil Research Department, from the spillway piers and inspection tunnel wall. The cores from the spillway piers (Appendix A, Figure A1) represented concrete exposed to a freeze-thaw environment and high relative humidity below the waterline. Cores from the inspection tunnel were obtained for comparison purposes and represented concrete exposed to relatively constant temperature and moisture conditions. To preserve the in-situ moisture condition, the core sections were sealed in plastic immediately after drilling. A core log, which identifies the core locations, is given in Appendix A.

The concrete in the cores appeared to be in good condition. Core breaks occurred both through and around the aggregate. The coarse aggregate, consisting of crushed rock, contained some elongated pieces. The maximum size of the aggregate varied between 25 and 60 mm. The aggregate grading was classified as good, and the distribution ranged from good to fair, with some core sections containing a high proportion of mortar. Evidence of extensive alkali-aggregate reactions, such as reaction rims around aggregates, reaction products deposited in voids or extensive cracking of the aggregate, was not observed in the concrete, although in a few localized areas the aggregates were cracked.

3.0 PETROGRAPHIC EXAMINATION

The petrographic examination consisted of microscopic observations of polished specimens and thin sections prepared from the cores. The results of the examination are reported in Appendix B.

Small amounts of alkali-silica reaction gel observed in the concrete were attributed to the presence of sand-size chert particles that had either partially or completely reacted. In general, the coarse aggregate particles, made up of gneisses, showed no indication of being reactive.

4.0 LABORATORY TESTING

Two laboratory test procedures were used to evaluate the concrete. The expansion was monitored by measuring the length change of core sections over a period of one year. The presence of reactive aggregates with potential for further expansion was determined using the Split Core test procedure. A brief description of the test procedures and the results are given below. Prior to starting the testing, the specimens were stored in the laboratory for approximately six months at 23°C and 100% relative humidity.

4.1 LENGTH CHANGE OF CONCRETE CORES

Specimens were prepared by cutting 250-mm sections from the cores and then fastening gauge points to the ends. The specimens were then stored at 38°C and 100% relative humidity. Length measurements were taken periodically for one year, and the change in length with time was used to evaluate the expansion of the concrete. The results of the length change measurements are given in Table 1 and Figures 1 and 2.

4.2 SPLIT CORE TEST PROCEDURE

The specimens for this test procedure consisted of 200-mm long sections cut from the cores, and these sections were then cut in half longitudinally. At two locations on the outside surface of each half, a set of Pfender gauges was attached. One half section was then placed in a lime water solution and the other half placed in a 1M NaOH solution. Length and weight measurements were taken periodically for one year. The expansion of the specimens in the two solutions was used to determine the presence of reactive aggregates and the potential for further expansion.

The length and weight change measurements are given in Table 2 and Figures 3 to 6. The length change of the specimens stored in the 1M NaOH solution was also plotted after subtracting the expansion of the cores stored in the lime water solution. (Figure 4).

5.0 DISCUSSION

For concrete exposed to freezing and thawing, the CSA standard suggests a maximum expansion of 0.04% at one year for specimens tested in accordance with CAN3-A23.2 14A (Concrete Prism Expansion Test).

It should be noted that after seven days the relative expansion of the specimens decreased significantly. The initial expansion may be associated with the concrete absorbing water and reaching equilibrium with the test environment. Even though one of the specimens exceeded the 0.04% expansion, the relatively stable condition of the cores after the initial 50 days indicated that the concrete was not expanding and therefore may not be reactive.

In the split core test procedure, an expansion of 0.03% after 28 days is considered significant. The specimens tested using this procedure did not expand more than 0.01% even after one year. This indicates that either the concrete is not reactive or that the reaction has reached completion.

6.0 CONCLUSION

Expansive alkali-aggregate reactions do not appear to be occurring in the concrete evaluated from Pine Portage GS. This conclusion is based on the petrographic examination and the laboratory testing of the concrete cores drilled from the spillway piers and the inspection tunnel wall.

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TABLE 1

PINE PORTAGE GS
EVALUATION OF CONCRETE FOR ALKALI-AGGREGATE REACTIVITY
LENGTH CHANGE OF CONCRETE CORES

EXPANSION (%)

DATE	TIME (days)	SPECIMEN 3-3	3-5	3-6	5-1	5-4	5-8	8-2
07-Apr-89	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14-Apr-89	7	0.015	0.009	0.010	0.010	0.015	0.027	0.009
21-Apr-89	14	0.015	0.009	0.011	0.011	0.016	0.032	0.012
05-May-89	28	0.017	0.011	0.014	0.013	0.020	0.035	0.018
02-Jun-89	56	0.016	0.010	0.014	0.011	0.020	0.031	0.025
30-Jun-89	84	0.016	0.010	0.014	0.011	0.020	0.031	0.027
28-Jul-89	112	0.016	0.010	0.015	0.014	0.020	0.031	0.030
25-Aug-89	140	0.019	0.015	0.017	0.017	0.022	0.037	0.042
22-Sep-89	168	0.011	0.015	0.016	0.005	0.014	0.026	0.024
17-Nov-89	224	0.019	0.014	0.016	0.014	0.022	0.036	0.034
12-Jan-9[illegible]	280	0.020	0.014	0.016	0.014	0.022	0.036	0.034
12-Mar-90	339	0.014	0.014	0.013	0.015	0.018	0.033	0.031
06-Apr-90	364	0.007	0.008	0.007	0.010	0.012	0.029	0.026

Maximum expansion suggested in CAN3-A23.2-M77 is 0.04% at one year.

SPECIMEN	LOCATION
3-3	Pier 6 upstream; depth in drill hole 660 to 1300 mm.
3-5	Pier 6 upstream; depth in drill hole 1420 to 1880 mm.
3-6	Pier 6 upstream; depth in drill hole 1880 to 2180 mm.
5-1	Pier 5 upstream; depth in drill hole 0 to 360 mm.
5-4	Pier 5 upstream; depth in drill hole 840 to 1270 mm.
5-8	Pier 5 upstream; depth in drill hole 1880 to 2390 mm.
8-2	Inspection tunnel; depth in drill hole 330 to 660 mm.

TABLE 2

PINE PORTAGE GS
EVALUATION OF CONCRETE FOR ALKALI-AGGREGATE REACTIVITY
SPLIT CORE TEST PROCEDURE

Specimen A - stored in lime water
Specimen B - stored in 1M NaOH solution

EXPANSION (%)

DATE	TIME (days)	SPECIMEN 1-2		3-5		4-1		5-8		8-1	
		A	B	A	B	A	B	A	B	A	B
23-Apr-89	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24-Apr-89	1	0.000	-0.004	0.001	-0.004	-0.000	-0.004	-0.001	-0.005	-0.001	-0.002
27-Apr-89	4	0.002	-0.001	0.002	0.002	0.000	0.001	0.000	-0.000	0.002	0.001
01-May-89	8	0.003	-0.001	0.002	0.003	0.000	0.000	-0.000	-0.003	0.002	0.004
08-May-89	15	0.005	0.001	0.003	0.007	0.003	0.002	0.000	-0.004	0.005	0.007
15-May-89	22	0.004	-0.001	0.003	0.007	0.002	-0.001	-0.001	-0.007	0.005	0.006
23-May-89	30	0.002	-0.004	0.000	0.005	-0.001	-0.003	-0.003	-0.010	0.003	0.005
19-Jun-89	57	0.006	0.001	0.004	0.009	0.002	0.000	0.000	-0.007	0.006	0.007
24-Jul-89	92	0.005	0.000	0.002	0.007	0.002	-0.001	-0.001	-0.008	0.006	0.007
25-Sep-89	155	0.003	-0.001	0.000	0.006	-0.001	-0.001	-0.002	-0.009	0.004	0.006
24-Nov-89	215	0.004	0.001	0.001	0.008	-0.001	-0.001	-0.002	-0.009	0.005	0.007
23-Feb-90	306	0.005	0.003	0.002	0.011	-0.001	0.003	-0.002	-0.005	0.004	0.012
24-Apr-90	366	0.005	0.005	0.004	0.014	0.001	0.005	0.000	-0.002	0.006	0.015

WEIGHT CHANGE (%)

DATE	TIME (days)	SPECIMEN 1-2		3-5		4-1		5-8		8-1	
		A	B	A	B	A	B	A	B	A	B
23-Apr-89	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24-Apr-89	1	0.020	0.038	0.075	0.054	0.033	0.040	0.041	0.049	0.021	0.033
27-Apr-89	4	0.034	0.082	0.075	0.098	0.033	0.073	0.066	0.082	0.042	0.079
01-May-89	8	0.054	0.088	0.097	0.119	0.059	0.080	0.058	0.082	0.042	0.092
08-May-89	15	0.020	0.133	0.075	0.163	0.033	0.114	0.033	0.132	0.035	0.132
15-May-89	22	0.034	0.209	0.086	0.217	0.039	0.134	0.050	0.165	0.049	0.171
23-May-89	30	0.041	0.196	0.054	0.249	0.046	0.160	0.050	0.173	0.049	0.191
19-Jun-89	57	0.034	0.265	0.118	0.314	0.059	0.214	0.066	0.239	0.055	0.270
24-Jul-89	92	0.061	0.303	0.108	0.423	0.085	0.287	0.074	0.296	0.076	0.349
25-Sep-89	155	0.122	0.455	0.140	0.542	0.163	0.408	0.107	0.387	0.111	0.475
24-Nov-89	215	0.129	0.505	0.172	0.629	0.137	0.448	0.124	0.403	0.153	0.534
23-Feb-90	306	0.163	0.506	0.194	0.662	0.130	0.494	0.124	0.436	0.166	0.613
24-Apr-90	366	0.041	0.455	0.086	0.618	0.052	0.434	0.008	0.378	0.090	0.560

SPECIMEN	LOCATION
1-2	Pier 7 upstream; depth in drill hole 360 - 690 mm.
3-5	Pier 6 upstream; depth in drill hole 1420 - 1880 mm.
4-1	Pier 6 downstream; depth in drill hole 0 - 260 mm.
5-8	Pier 5 upstream; depth in drill hole 1800 - 2390 mm.
8-1	Inspection tunnel; depth in drill hole 0 - 330 mm.

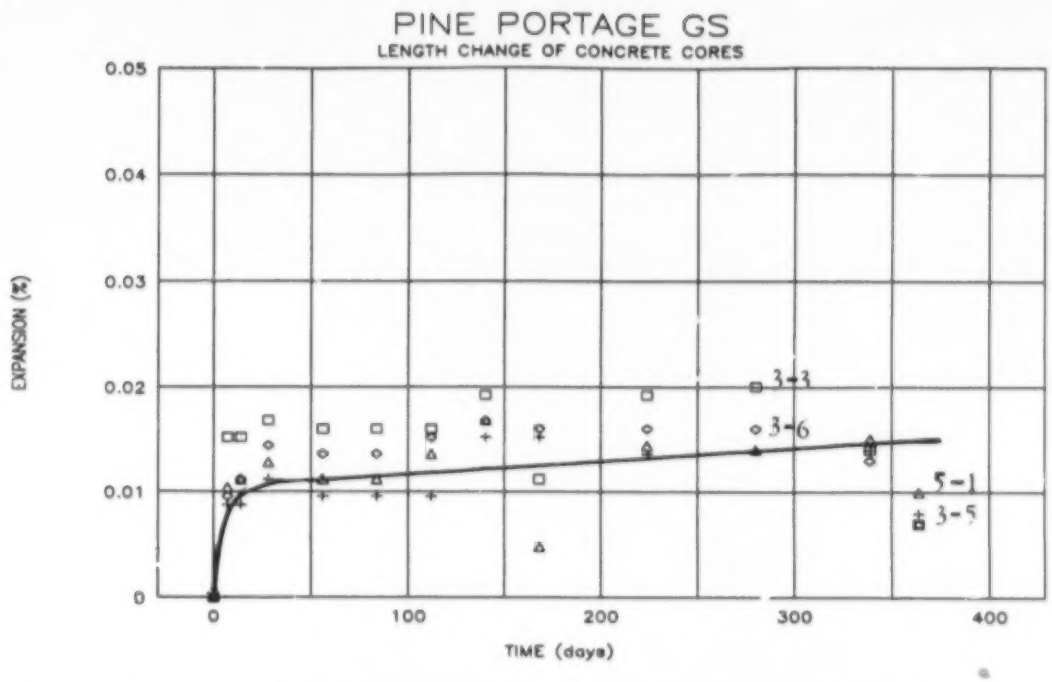


Figure 1 - Length change of concrete core specimens stored at 38°C and 100% relative humidity.

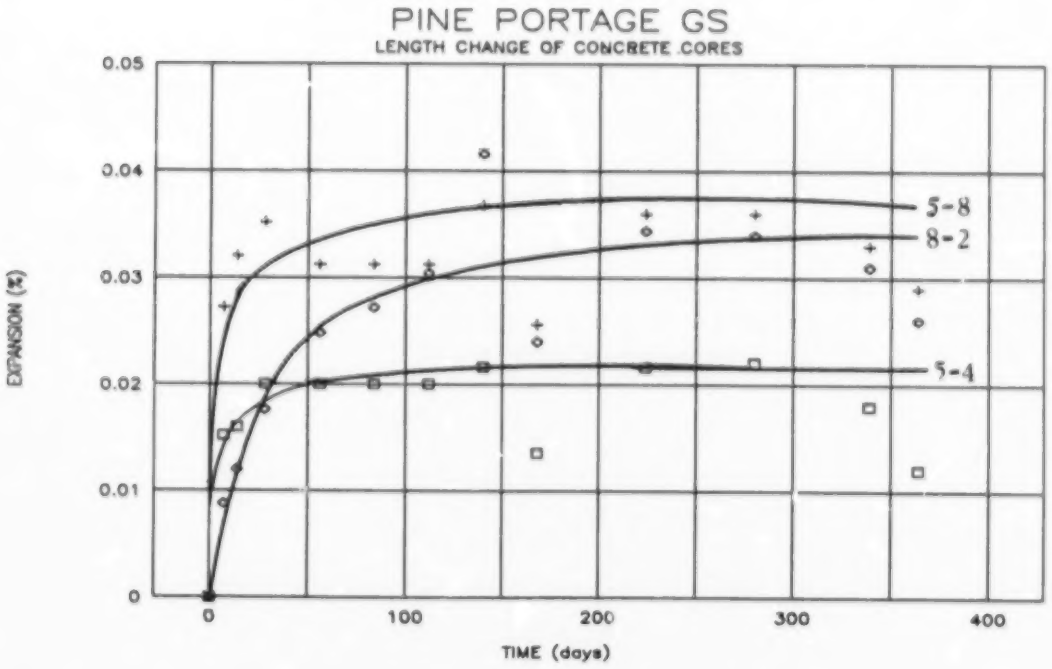


Figure 2 - Length change of concrete core specimens stored at 38°C and 100% relative humidity.

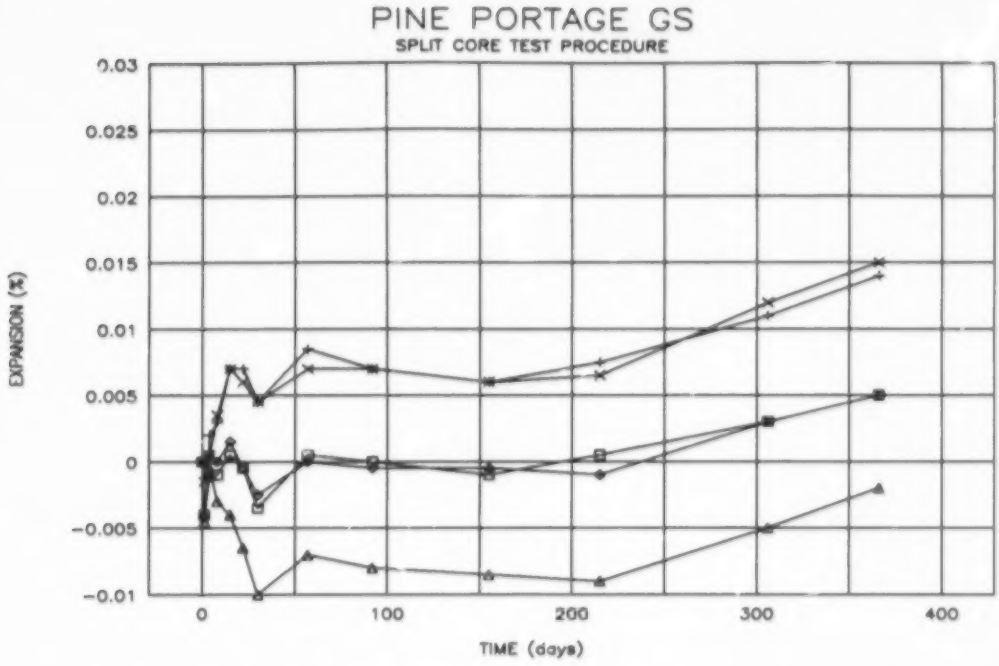


FIGURE 3 - Expansion of split core specimens stored in a 1M NaOH solution.

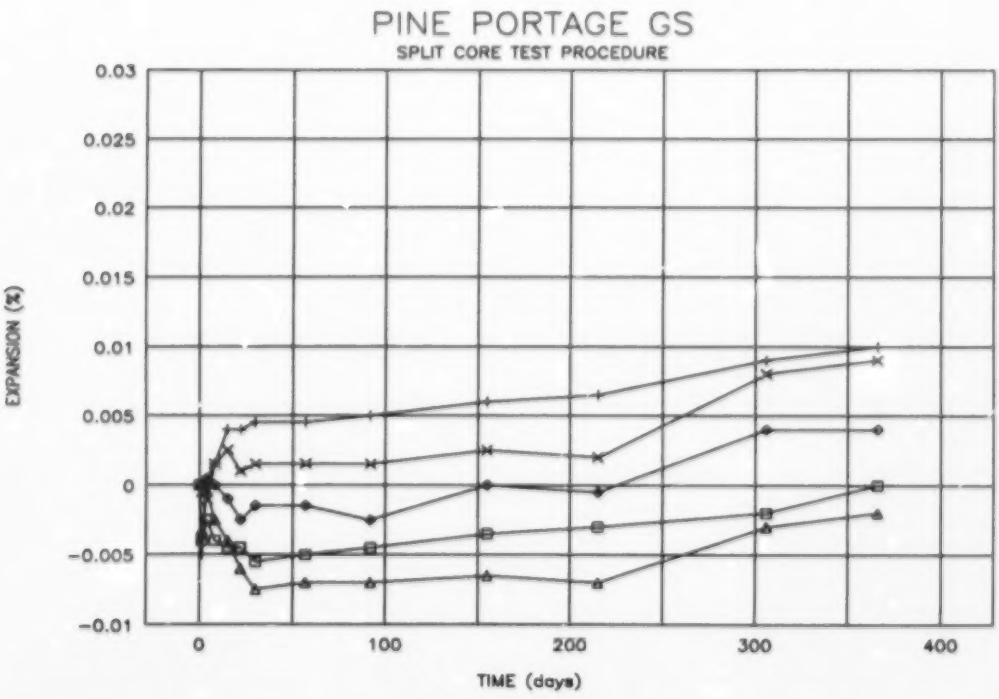


FIGURE 4 - Difference in expansion of split core specimens stored in a 1M NaOH solution and in a lime water solution.

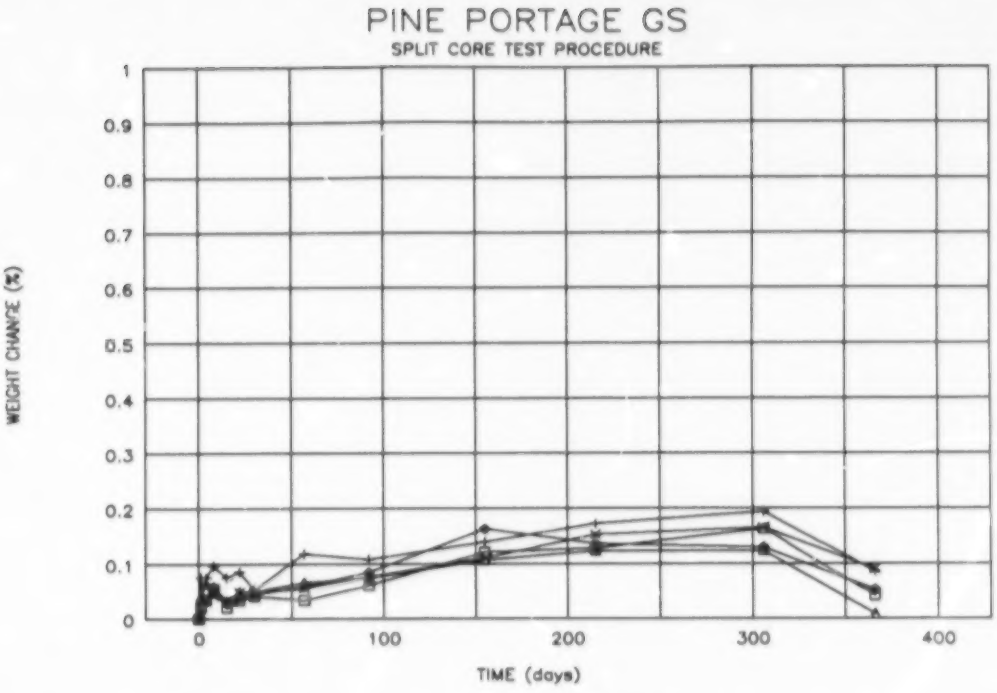


FIGURE 5 - Weight change of specimens stored in a lime water solution.

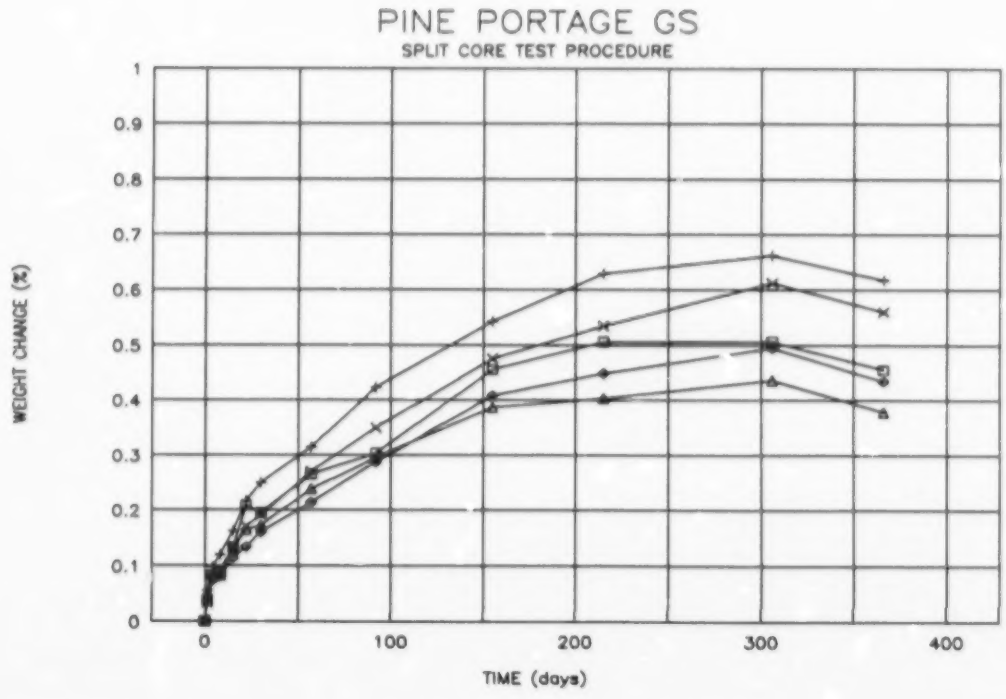


FIGURE 6 - Weight change of specimens stored in a 1M NaOH solution.

APPENDIX A

PINE PORTAGE GS
CONCRETE CORE LOG

APPENDIX A

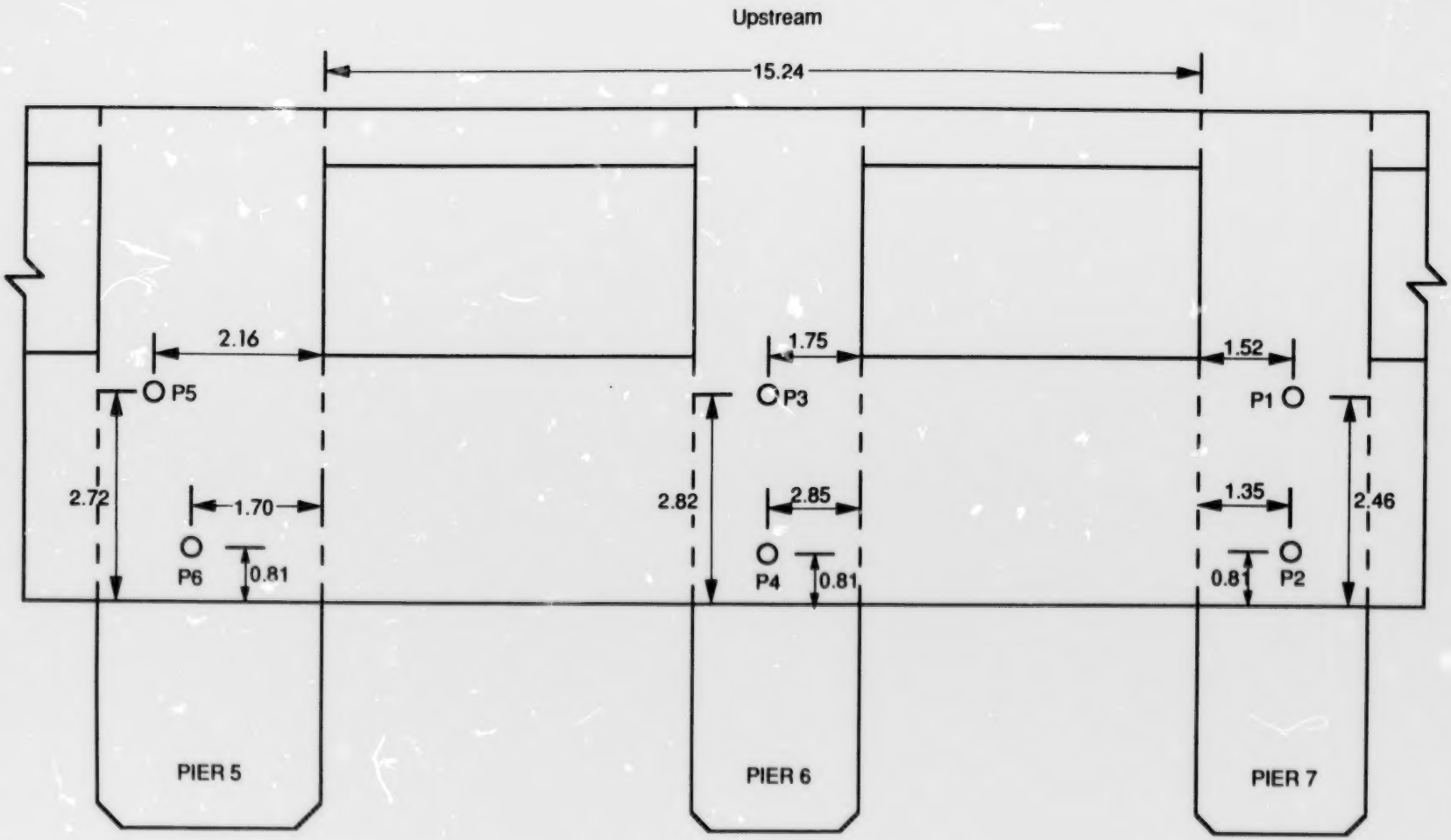
PINE PORTAGE GS
CONCRETE CORE LOG

Core Number and Location	Core Section Identification	Location in core (mm)	Remarks
P 1	1 - 1	0 - 360	- Core Sections 4-1 to 4-4 are 95 mm diameter; remainder of core sections are 85 mm diameter
Pier 7 Upstream (See Figures A1 and A2)	1 - 2	360 - 690	
	1 - 3	690 - 1040	
	1 - 4	1040 - 1140	- Maximum aggregate size 50 mm
	1 - 5	1140 - 1280	- Cracks extend 15 mm below top of core
	1 - 6	1280 - 1480	
	1 - 7	1480 - 1570	- Ends of Core Sections 1-5 to 1-9 ground during drilling
	1 - 8	1570 - 1710	
	1 - 9	1710 - 1830	
P 2	2 - 1	0 - 260	- Core 95 mm diameter
Pier 7 Downstream (See Figures A1 and A3)	2 - 2	260 - 410	- One 15 mm diameter steel reinforcing bar at 300 mm
	2 - 3	410 - 510	
	2 - 4	510 - 690	- Maximum aggregate size 40 mm
P 3	3 - 1	0 - 360	- Core Sections 3-1 and 3-2 are 95 mm diameter; remainder of core sections are 85 mm diameter
Pie 6 Upstream (See Figures A1 and A2)	3 - 2	360 - 660	
	3 - 3	660 - 1300	
	3 - 4	1300 - 1420	- Maximum aggregate size 25 mm
	3 - 5	1420 - 1880	
	3 - 6	1880 - 2180	
P 4	4 - 1	0 - 260	- Core 95 mm diameter
Pier 6 Downstream (See Figures A1 and A3)	4 - 2	260 - 610	- One 15 mm diameter steel reinforcing bar at 120 mm
			- Maximum aggregate size 40 mm
P 5	5 - 1	0 - 360	- Core Sections 5-1 and 5-2 are 95 mm diameter; remainder of core sections are 85 mm diameter
Pier 5 Upstream (See Figures A1 and A2)	5 - 2	360 - 660	
	5 - 3	660 - 840	
	5 - 4	840 - 1270	
	5 - 5	1270 - 1400	- Maximum aggregate size 25 mm
	5 - 6	1400 - 1600	- Crack extends 55 mm from top of core
	5 - 7	1600 - 1880	
	5 - 8	1880 - 2390	

APPENDIX A

PINE PORTAGE GS
CONCRETE CORE LOG

Core Number and Location	Core Section Identification	Location in core (mm)	Remarks
P 6 Pier 5 Downstream (See Figures A1 and A3)	6 - 1 6 - 2	0 - 360 360 - 610	- Core 95 mm diameter - Maximum aggregate size 25 mm
G 1 Inspection tunnel entrance upstream wall (See Figure A4)	7 - 1 7 - 2	0 - 330 330 - 690	- Core 95 mm diameter - Two 20 mm diameter steel reinforcing bars at 100 mm - Maximum aggregate size 60 mm
G 2 Inspection tunnel entrance, upstream wall (See Figure A4)	8 - 1 8 - 2	0 - 330 330 - 660	- Core 95 mm diameter - One 20 mm diameter steel reinforcing bar at 100 mm - Maximum aggregate size 40 mm



Note: All Dimensions are in Meters

FIGURE A1

PINE PORTAGE GS SPILLWAY PIERS, LOCATION OF CORE HOLES

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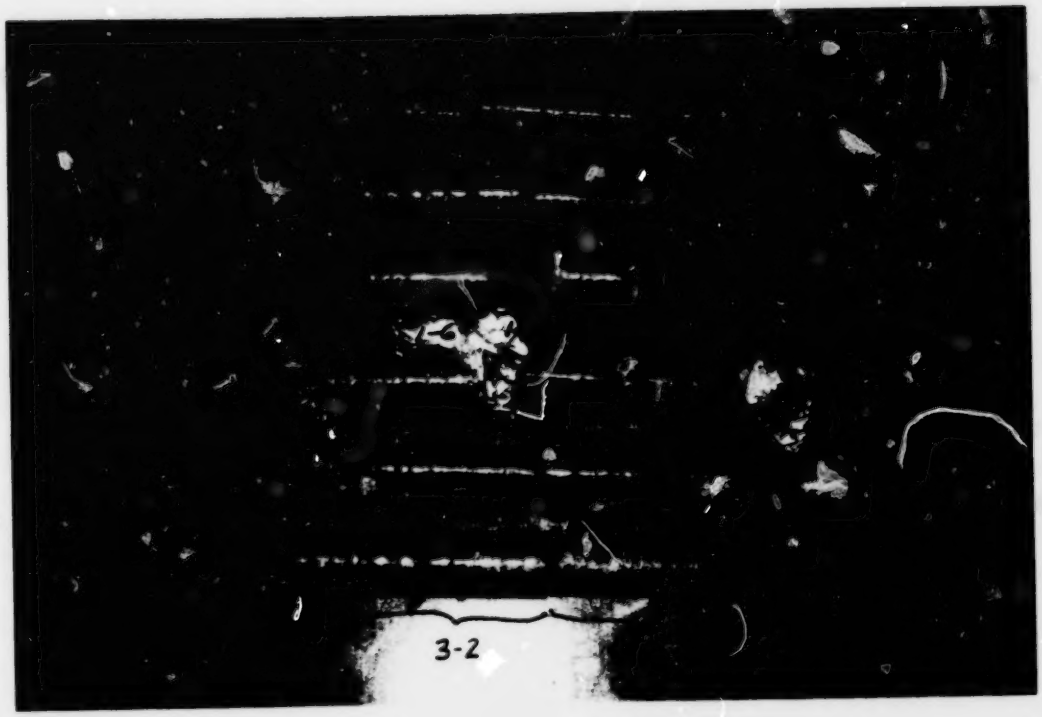

Figure A2 - Cores P1, P3 and P5 identified by section.

Figure A3 - Cores P2, P4 and P6 identified by section.

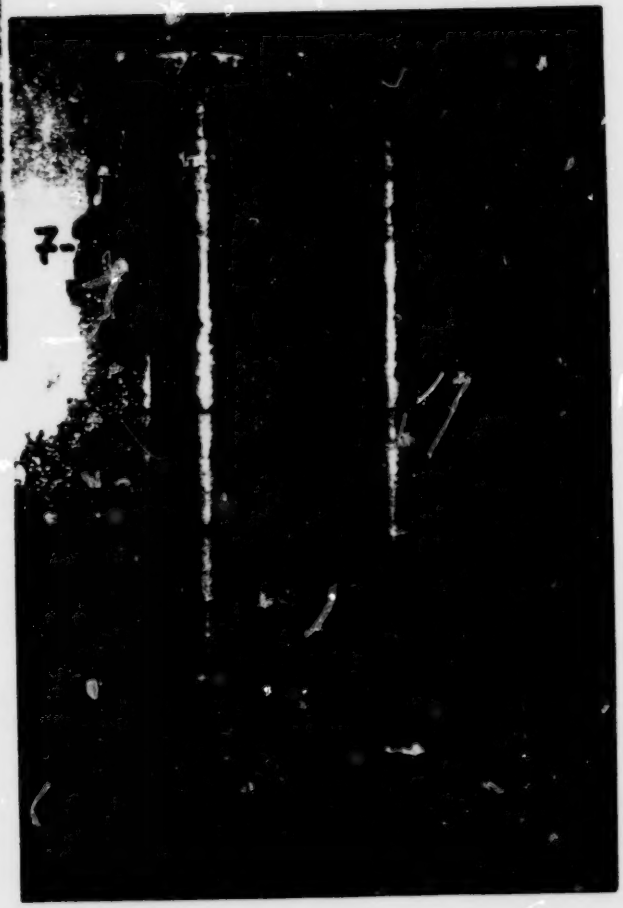

Figure A4 - Cores G1 and G2 identified by section.

APPENDIX B

PINE PORTAGE GS
PETROGRAPHIC EXAMINATION OF CONCRETE

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PINE PORTAGE GS
PETROGRAPHIC EXAMINATION OF CONCRETE CORES

M.F. Everitt

1.0 INTRODUCTION

The Concrete Technology Section, Civil Research Department, is currently conducting an investigation into the presence of alkali-aggregate reactivity of the concrete in the Pine Portage GS Dam. This report includes results of a petrographic examination of core samples obtained from various locations of the dam. The examination included a visual assessment of the cores for evidence of alkali-aggregate reactions and other signs of deterioration. Polished specimens and thin sections were also prepared and examined microscopically to assist in evaluating the condition of the concrete and identifying the rock types comprising the aggregates.

2.0 PETROGRAPHIC EXAMINATION

Four core sections (2-1, 3-2, 3-4, 5-7) from the spillway piers and one section (7-1) from the inspection tunnel were examined. Concrete from the spillway piers has undergone approximately 40 years of exposure in an outdoor environment of high relative humidity. For the same duration of time, concrete from the inspection tunnel has undergone exposure in an indoor environment. A detailed petrographic examination of specimens from these sections of core is included in Attachments 1 to 5. Except for minor variations in aggregate distribution and size, the concrete specimens are petrographically similar and can be summarized as a group.

2.1 Visual and Stereoscopic Examination

In general, the concrete consists of 28 mm nominal maximum size coarse aggregate comprised of crushed, angular to sub-angular, biotite garnet gneiss and other gneisses with minor amounts of iron formation, sandstone and chert, in a dull, light grey

non-air-entrained cement paste. Darkening of the cement paste around some coarse aggregate particles has occurred and indicates the presence of alkali-silica gel. Some sections contain a concentration of large aggregates, while others contain only mortar.

Coarse aggregate particles tend to be flat or elongated and show preferred orientation in a direction parallel to the concrete surface. Construction records state that the coarse aggregate was obtained from the site excavation. Rocks underlying the Pine Portage GS site include Early Precambrian metasediments and related migmatites. The fine aggregate consists of sub-rounded to sub-angular quartz, feldspar and volcanics, with minor amounts of sandstone and chert. The sources of the fine aggregate are pits at Fraser Creek and Bass Creek. Entrapped air voids are irregularly shaped, and some are either partly lined or filled with portlandite and/or alkali-silica gel.

Cracking of the cores consists of a series of randomly oriented, discontinuous microcracks (<0.1 mm wide) which run both around and through the coarse aggregate particles. Cracks associated with sand-sized chert particles are frequently filled with alkali-silica gel.

2.2 Thin Section Examination

In plane transmitted light, the cement paste is blotchy, consisting of pale tan matter, indicative of normal cement hydration, grading to a dark brown or black gel soaked paste (see Figure 1).

Areas of gel soaked paste are concentrated along microcracks and the periphery of the coarse aggregate particles. Microcracks appear to originate at chert particles that have either partially or totally gelatinized (see Figure 2).

The interface between the coarse aggregate particles and the cement paste is predominantly nonreactive (see Figure 3). Microcracks bounded on either side by gel-rich cement paste commonly terminate at coarse aggregate particles (see Figure 4) with the exception of a small percentage (<5%) of gneisses derived from fine grained siliceous parent rocks (see Figure 5 and 6).

3.0 CONCLUSIONS

a) The presence of minor amounts of alkali-silica reaction gel was noted in the concrete. The effects of these reactions are minor and limited to localized, discontinuous microcracks (<0.1 mm wide) associated with sand-sized chert particles. These chert particles have been either partially or completely gelatinized, depending on the extent to which reaction with the cement-alkalies has progressed.

b) With the exception of migmatites derived from fine grained siliceous parent rocks, the coarse aggregate particles are nonreactive.

c) The extent and type of alkali-aggregate reactions observed within the concrete from the spillway piers and the inspection tunnel were similar.

d) Flat and elongated coarse aggregate particles exhibiting a preferred orientation parallel to the concrete surface were noted. An uneven distribution of aggregate particles was observed in the concrete. In some sections, a concentration of large size particles was evident, while in others only mortar fraction occurred indicating aggregate segregation.

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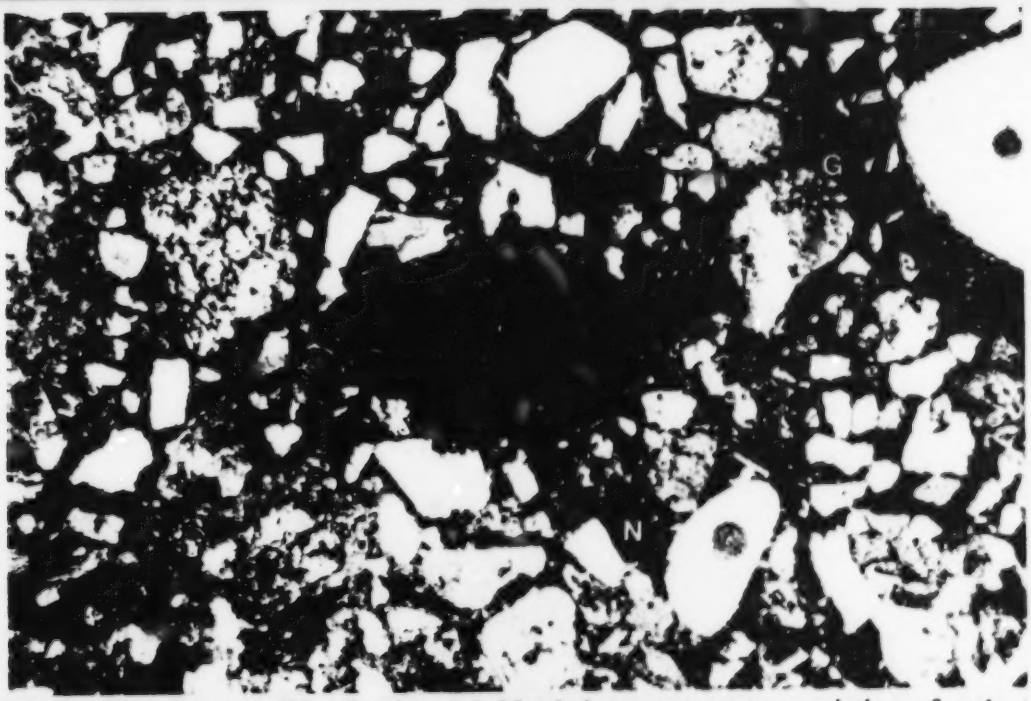

FIGURE 1 - Pine Portage GS: Section 5-7 Mottled cement paste consisting of pale tan coloured matter (N) indicative of normal cement hydration grading to black gel soaked paste (G) (LTS 16, Analyzer out, Mag. 5.1X).

FIGURE 2 - Pine Portage GS: Section 2-1 Partially gelatinized chert particle (C) associated with microcracks (M). Gel (G) appears to have migrated along microcracks into a void (V) (LTS 17, Analyzer out, Mag. 10.2X).

FIGURE 3 - Pine Portage GS: Section 3-4 Non-reactive boundary (B) between a biotite garnet gneiss coarse aggregate (A) and the cement paste (P) (LTS 15, Analyzer out, mag. 20.2X).

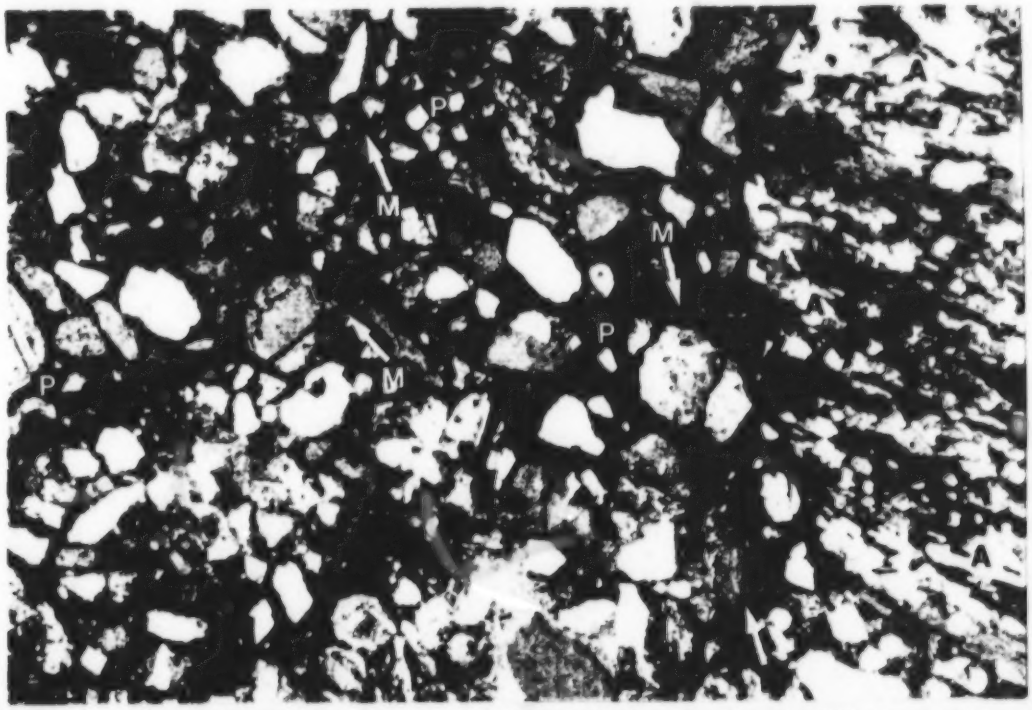

FIGURE 4 - Pine Portage GS: Section 3-4 Gel soaked cement paste (P) along microcracks (M) which terminate at a coarse aggregate particle (A) (LTS 15, Analyzer out, Mag. 5.1X).

FIGURE 5 - Pine Portage GS: Section 2-1 Reactive migmatite derived from a fine grained siliceous parent rock (Ch) associated with a gel (G) lined microcrack (M) extending into the cement paste. (LTS 17, Analyzer out, Mag. 32X).

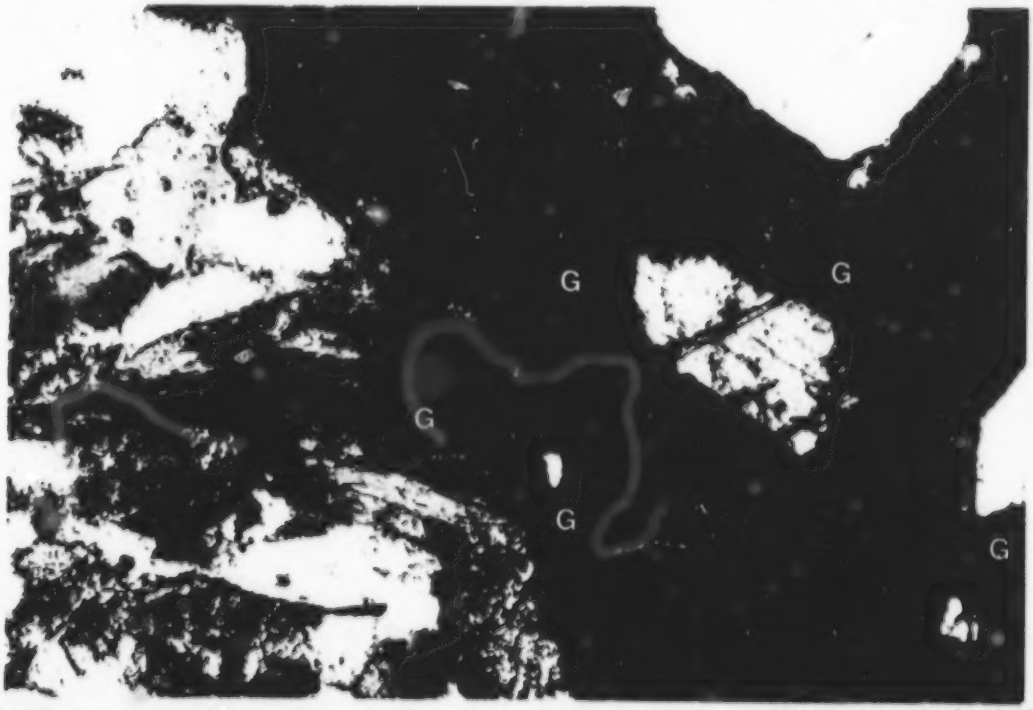

FIGURE 6 - Pine Portage GS: Section 2-1. Same as above under cross polarized light. Note the cloudy nature of the cement matrix typical of gel-soaked paste (G). (LTS 17, Analyzer out, Mag. 32X).

ATTACHMENT 1-5

ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE

Project :	Pine Portage GS	**Job No.** :	42-113-581
Region :	Northwestern	**File No.** :	842.52 PIN
Area :	Thunder Bay	**Report No.** :	SN89-4-K
Structure :	Inspection Tunnel	**Date Issued** :	August 18, 1989

Sample Type : **Core** [X] **Cylinder** [ ] **Chunk** [ ]

Sample Description : Section 7-1 (interval 0 mm - 330 mm, nominal 95 mm diameter) taken from the upstream wall at the west tunnel entrance. The concrete has undergone approximately 40 years of exposure in an indoor environment.

Sample Preparation : **Freshly broken surface** [ ] **Weathered surface** [ ] **Polished face** [X] **Thin Section** [X] / **No.** LTS 13

CONCRETE

Hit with hammer	:	**Ring** [X]		**Dull** [ ]		
Break with fingers	:	**Particles not dislodged** [X]		**Powdery** [ ]	**Friable** [ ]	
During sawing	:	**Clean cut** [X]		**Breaks easily** [ ]		
Cement / coarse aggregate bond	:	**Good** [X]		**Partial** [ ]	**Poor** [ ]	
Cement / fine aggregate bond	:	**Good** [X]		**Partial** [ ]	**Poor** [ ]	
Presence of honeycombing	:	**Not observed** [X]		**Minor** [ ]	**Extensive** [ ]	

COARSE AGGREGATE

Source	:	Bedrock from site excavations.			
% of total volume	:	45-50 %	**Visual estimate** [X]	**Point count** [ ]	
Material type	:	**Gravel** [ ]	**Quarried** [X]	**Mixture** [ ]	**Other -**
Shape	:	**Rounded** [ ]	**Partly crushed** [ ]	**100 % Crushed** [X]	
Distribution	:	**Even** [ ]	**Uneven** [X]	**Chaotic** [ ]	
Nominal size	:	28 (mm)			
Maximum size	:	60 (mm)			
Preferred orientation	:	**Present** [X]	**Not observed** [ ]		

LITHOLOGICAL TYPE	% OF COARSE AGGREGATE	REACTION RIMS / GEL / FRACTURES	REMARKS
Biotite garnet gneiss	85 - 90	Tight fractures through some particles. No mineralization along fractures.	Migmatites derived from sandstone, chert, iron formation and metasediments.
Other gneisses and volcanics	5 - 10	Same as above.	Same as above.
Iron formation and sandstone	3 - 5	———	———

FINE AGGREGATE

Source	:	Pits at Fraser Creek and Bass Creek.				
% of total volume	:	30-35 %	**Visual estimate** [X]	**Point count** [ ]		
Material type	:	**Natural** [X]	**Manufactured** [ ]	**Mixture** [ ]	**Other -**	
Shape	:	**Rounded** [ ]	**Subrounded** [X]	**Subangular** [X]	**Angular** [ ]	
Distribution	:	**Even** [X]	**Uneven** [ ]	**Chaotic** [ ]		
Preferred orientation	:	**Present** [ ]	**Not observed** [X]			

cont.

CEMENT MATRIX

% of total volume : 10-15 % Visual estimate [X] Point count [ ]
Appearance of broken surface : Subtranslucent [ ] Dull [X] Chalky [ ]
Colour : Grey [X] Light Grey [X] White [ ] Brown [ ] Other -
Colour distribution : Even [ ] Mottled [X] Gradational [ ]
Bleeding : Extensive [ ] Minor [X] Not observed [ ]
Carbonation : Surficial only [X] Along fractures [ ] Partial [ ] Total [ ]
Slag cement : Observed [ ] Not observed [X]
Fly ash : Observed [ ] Not observed [X]

VOIDS

% of total volume : 3-5 % Visual estimate [X] Point count [ ]
Distribution : Even [ ] Uneven [X] Clustered [ ]
Shape : Spherical [ ] Nonspherical [ ] Ellipsoidal [ ] Irregular [X]
Entrained air : Air-entrained [ ] Non-air-entrained [X]
Interior lustre : Dull [X] Shining [ ]
Interior condition : Empty [X] Lined [X] Partly filled [ ] Totally filled [ ]
% Voids with mineralization : Most [ ] About half [ ] Few [X] None [ ]
Mineralization : Alkali-silica gel [ ] Ettringite [ ] Portlandite [ ] Calcium carbonate [X]

CRACKS

Amount : Extensive [ ] Occasional [X] None [ ]
Continuity and Distribution : Discontinuous, localized cracks.

Orientation : Vertical [ ] Horizontal [ ] Random [X]
Location : Through aggregate particles [X] Around aggregate particles [ ]
Width (mm) : Range 0.1 to 0.2 Average < 0.1
% filled : < 10 %
Filling material : Alkali-silica gel [X] Ettringite [ ] Portlandite [ ]
Calcium carbonate [ ] Other -
Associated with embedded items : Yes [ ] No [X]

EMBEDDED ITEMS

Yes [X] No [ ]

Description : 2 steel reinforcing bars.
Condition : Clean [X] Corroded [ ] Decayed [ ]
Size (mm) : 20 mm diameter.
Location / Orientation : Depth of 100 mm in horizontal orientation.
Other : Entrapped air voids along the periphery of the reinforcing bars.

GENERAL COMMENTS

Elongated coarse aggregate particles show a preferred orientation parallel to the concrete surface. Darkening of the cement paste around some particles indicates the presence of alkali-silica gel. A few sand-sized, gel rimmed chert particles were noted.

Approved by : P.K. Mukherjee Submitted by : M.K.

Distribution : Mr. P.K. Mukherjee, Mr. E.J. McColm, Mr. D.G. Wilkinson, Original to Mr. M.F. Everitt, Official Record

Report No : SN89-4-K

S8927

89-255

ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE

Project :	Pine Portage GS	**Job No.** :	42-113-581
Region :	Northwestern	**File No.** :	842.52 PIN
Area :	Thunder Bay	**Report No.** :	SN89-5-K
Structure :	Spillway Pier 7	**Date Issued** :	August 18, 1989

Sample Type : **Core** [X] **Cylinder** [ ] **Chunk** [ ]

Sample Description : Section 2-1 (interval 0 mm - 260 mm, nominal 95 mm diameter) taken from the downstream end. The concrete has undergone approximately 40 years of exposure in an environment of high relative humidity.

Sample Preparation : **Freshly broken surface** [ ] **Weathered surface** [ ] **Polished face** [X] **Thin Section** [X] / **No.** LTS 17

CONCRETE

Hit with hammer	:	**Ring** [X]	**Dull** [ ]			
Break with fingers	:	**Particles not dislodged** [X]	**Powdery** [ ]	**Friable** [ ]		
During sawing	:	**Clean cut** [X]	**Breaks easily** [ ]			
Cement / coarse aggregate bond	:	**Good** [X]	**Partial** [ ]	**Poor** [ ]		
Cement / fine aggregate bond	:	**Good** [X]	**Partial** [ ]	**Poor** [ ]		
Presence of honeycombing	:	**Not observed** [X]	**Minor** [ ]	**Extensive** [ ]		

COARSE AGGREGATE

Source	:	Bedrock from site excavations.			
% of total volume	:	35-40 %	**Visual estimate** [X]	**Point count** [ ]	
Material type	:	**Gravel** [ ]	**Quarried** [X]	**Mixture** [ ]	**Other** -
Shape	:	**Rounded** [ ]	**Partly crushed** [ ]	**100 % Crushed** [X]	
Distribution	:	**Even** [ ]	**Uneven** [X]	**Chaotic** [ ]	
Nominal size	:	28 (mm)			
Maximum size	:	50 (mm)			
Preferred orientation	:	**Present** [X]	**Not observed** [ ]		

LITHOLOGICAL TYPE	% OF COARSE AGGREGATE	REACTION RIMS / GEL / FRACTURES	REMARKS
Biotite garnet gneiss	80 - 85	Tight fractures through and around coarse aggregate particles.	Migmatites derived from sandstone, chert, iron formation and metasediments.
Other gneisses and volcanics	10 - 15	Same as above	Same as above
Iron formation	3 - 5	_____	_____

FINE AGGREGATE

Source	:	Pits at Fraser Creek and Bass Creek.				
% of total volume	:	35-40 %	**Visual estimate** [X]	**Point count** [ ]		
Material type	:	**Natural** [X]	**Manufactured** [ ]	**Mixture** [ ]	**Other** -	
Shape	:	**Rounded** [ ]	**Subrounded** [X]	**Subangular** [X]	**Angular** [ ]	
Distribution	:	**Even** [X]	**Uneven** [ ]	**Chaotic** [ ]		
Preferred orientation	:	**Present** [ ]	**Not observed** [X]			

cont.

CEMENT MATRIX

% of total volume : 20-25 % Visual estimate [X] Point count [ ]
Appearance of broken surface : Subtranslucent [ ] Dull [X] Chalky [ ]
Colour : Grey [ ] Light Grey [X] White [ ] Brown [ ] Other -
Colour distribution : Even [X] Mottled [ ] Gradational [ ]
Bleeding : Extensive [ ] Minor [ ] Not observed [X]
Carbonation : Surficial only [X] Along fractures [ ] Partial [ ] Total [ ]
Slag cement : Observed [ ] Not observed [X]
Fly ash : Observed [ ] Not observed [X]

VOIDS

% of total volume : 3-5 % Visual estimate [X] Point count [ ]
Distribution : Even [ ] Uneven [X] Clustered [ ]
Shape : Spherical [ ] Nonspherical [ ] Ellipsoidal [ ] Irregular [X]
Entrained air : Air-entrained [ ] Non-air-entrained [X]
Interior lustre : Dull [X] Shining [ ]
Interior condition : Empty [X] Lined [ ] Partly filled [X] Totally filled [ ]
% Voids with mineralization : Most [ ] About half [ ] Few [X] None [ ]
Mineralization : Alkali-silica gel [ ] Ettringite [ ] Portlandite [X] Calcium carbonate [ ]

CRACKS

Amount : Extensive [ ] Occasional [X] None [ ]
Continuity and Distribution : Discontinuous and evenly distributed.

Orientation : Vertical [ ] Horizontal [ ] Random [X]
Location : Through aggregate particles [X] Around aggregate particles [X]
Width (mm) : Range 0.1 to 0.2 Average < 0.1
% filled : 10-20 %
Filling material : Alkali-silica gel [X] Ettringite [ ] Portlandite [ ]
Calcium carbonate [ ] Other -
Associated with embedded items : Yes [ ] No [X]

EMBEDDED ITEMS Yes [ ] No [X]

Description :
Condition : Clean [ ] Corroded [ ] Decayed [ ]
Size (mm) :
Location / Orientation :
Other :

GENERAL COMMENTS

Elongated coarse aggregate particles show a preferred orientation parallel to the concrete surface.

Approved by : Submitted by :

Distribution : Mr. P.K. Mukherjee, Mr. E.J. McColm, Mr. D.G. Wilkinson, Original to Mr. M.F. Everitt, Official Record

Report No : SN89-5-K

S89-27
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ATTACHMENT 3

ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE

Project :	Pine Portage GS	**Job No.** :	42-113-581
Region :	Northwestern	**File No.** :	842.52 PIN
Area :	Thunder Bay	**Report No.** :	SN89-6-K
Structure :	Spillway Pier 6	**Date Issued** :	August 18, 1989

Sample Type : **Core** [X] **Cylinder** [ ] **Chunk** [ ]

Sample Description : Section 3-2 (interval 360 mm - 660 mm, nominal 95 mm diameter) taken from the upstream end. The concrete has undergone approximately 40 years of exposure in an environment of high relative humidity.

Sample Preparation : **Freshly broken surface** [ ] **Weathered surface** [ ] **Polished face** [X] **Thin Section** [X] / **No.** LTS 14

CONCRETE

Hit with hammer	:	**Ring** [X]	**Dull** [ ]			
Break with fingers	:	**Particles not dislodged** [X]	**Powdery** [ ]	**Friable** [ ]		
During sawing	:	**Clean cut** [X]	**Breaks easily** [ ]			
Cement / coarse aggregate bond	:	**Good** [X]	**Partial** [ ]	**Poor** [ ]		
Cement / fine aggregate bond	:	**Good** [X]	**Partial** [ ]	**Poor** [ ]		
Presence of honeycombing	:	**Not observed** [X]	**Minor** [ ]	**Extensive** [ ]		

COARSE AGGREGATE

Source	:	Bedrock from site excavations.			
% of total volume	:	40-45 %	**Visual estimate** [X]	**Point count** [ ]	
Material type	:	**Gravel** [ ]	**Quarried** [X]	**Mixture** [ ]	**Other -**
Shape	:	**Rounded** [ ]	**Partly crushed** [ ]	**100 % Crushed** [X]	
Distribution	:	**Even** [ ]	**Uneven** [X]	**Chaotic** [ ]	
Nominal size	:	28 (mm)			
Maximum size	:	28 (mm)			
Preferred orientation	:	**Present** [X]	**Not observed** [ ]		

LITHOLOGICAL TYPE	% OF COARSE AGGREGATE	REACTION RIMS / GEL / FRACTURES	REMARKS
Biotite garnet gneiss	80 - 85	Tight fractures through and around coarse aggregate particles.	Migmatites derived from sandstone, chert, iron formation and metasediments.
Other gneisses and volcanics	15 - 20	Same as above.	Same as above.
Iron Formation	3 - 5	_____	_____

FINE AGGREGATE

Source	:					
% of total volume	:	%	**Visual estimate** [X]	**Point count** [ ]		
Material type	:	**Natural** [X]	**Manufactured** [ ]	**Mixture** [ ]	**Other -**	
Shape	:	**Rounded** [ ]	**Subrounded** [X]	**Subangular** [X]	**Angular** [ ]	
Distribution	:	**Even** [X]	**Uneven** [ ]	**Chaotic** [ ]		
Preferred orientation	:	**Present** [ ]	**Not observed** [X]			

cont.

CEMENT MATRIX

% of total volume :	15-20 %	Visual estimate [X]		Point count [ ]	
Appearance of broken surface :		Subtranslucent [ ]		Dull [X]	Chalky [ ]
Colour :	Grey [ ]	Light Grey [X]	White [ ]	Brown [ ]	Other -
Colour distribution :	Even [X]	Mottled [ ]		Gradational [ ]	
Bleeding :	Extensive [ ]	Minor [ ]		Not observed [X]	
Carbonation :	Surficial only [X]	Along fractures [ ]		Partial [ ]	Total [ ]
Slag cement :	Observed [ ]	Not observed [X]			
Fly ash :	Observed [ ]	Not observed [X]			

VOIDS

% of total volume :	3-5 %	Visual estimate [X]		Point count [ ]	
Distribution :	Even [ ]	Uneven [X]		Clustered [ ]	
Shape :	Spherical [ ]	Nonspherical [ ]		Ellipsoidal [ ]	Irregular [X]
Entrained air :	Air-entrained [ ]	Non-air-entrained [X]			
Interior lustre :	Dull [X]	Shining [X]			
Interior condition :	Empty [X]	Lined [X]		Partly filled [X]	Totally filled [X]
% Voids with mineralization :	Most [ ]	About half [X]		Few [ ]	None [ ]
Mineralization :	Alkali-silica gel [X]	Ettringite [ ]		Portlandite [X]	Calcium carbonate [ ]

CRACKS

Amount : Extensive [ ] Occasional [X] None [ ]

Continuity and Distribution : Some cracks are continuous across the core.

Orientation :	Vertical [ ]	Horizontal [X]		Random [ ]
Location :	Through aggregate particles [X]			Around aggregate particles [X]
Width (mm) :	Range 0.1 to 0.2	Average < 0.1		
% filled :	35-40 %			
Filling material :	Alkali-silica gel [X]	Ettringite [ ]		Portlandite [X]
	Calcium carbonate [ ]	Other -		
Associated with embedded items :	Yes [ ]	No [X]		

EMBEDDED ITEMS Yes [ ] No [X]

Description :
Condition : Clean [ ] Corroded [ ] Decayed [ ]
Size (mm) :
Location / Orientation :
Other :

GENERAL COMMENTS

Elongated coarse aggregate particles show a preferred orientation parallel to the concrete surface.

Approved by : Submitted by :

Distribution : Mr. P.K. Mukherjee, Mr. E.J. McColm, Mr. D.G. Wilkinson, Original to Mr. M.F. Everitt, Official Record

Report No : SN89-6-K

S89-27
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ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE

Project :	Pine Portage GS	**Job No.** :	42-113-581
Region :	Northwestern	**File No.** :	842.52 PIN
Area :	Thunder Bay	**Report No.** :	SN89-7-K
Structure :	Spillway Pier 6	**Date Issued** :	August 18, 1989

Sample Type : **Core** [X] **Cylinder** [ ] **Chunk** [ ]

Sample Description : Section 3-4 (interval 1300 mm - 1420 mm, nominal 85 mm diameter) taken from the upstream end. The concrete has undergone approximately 40 years of exposure in an environment of high relative humidity.

Sample Preparation : **Freshly broken surface** [ ] **Weathered surface** [ ] **Polished face** [X] **Thin Section** [X] / **No.** LTS 15

CONCRETE

Hit with hammer	:	**Ring** [X]		**Dull** [ ]		
Break with fingers	:	**Particles not dislodged** [X]		**Powdery** [ ]	**Friable** [ ]	
During sawing	:	**Clean cut** [X]		**Breaks easily** [ ]		
Cement / coarse aggregate bond	:	**Good** [X]		**Partial** [ ]	**Poor** [ ]	
Cement / fine aggregate bond	:	**Good** [X]		**Partial** [ ]	**Poor** [ ]	
Presence of honeycombing	:	**Not observed** [X]		**Minor** [ ]	**Extensive** [ ]	

COARSE AGGREGATE

Source	:	Bedrock from site excavations.			
% of total volume	:	30-35 %	**Visual estimate** [X]	**Point count** [ ]	
Material type	:	**Gravel** [ ]	**Quarried** [X]	**Mixture** [ ]	**Other** -
Shape	:	**Rounded** [ ]	**Partly crushed** [ ]	**100 % Crushed** [X]	
Distribution	:	**Even** [ ]	**Uneven** [X]	**Chaotic** [ ]	
Nominal size	:	28 (mm)			
Maximum size	:	28 (mm)			
Preferred orientation	:	**Present** [X]	**Not observed** [ ]		

LITHOLOGICAL TYPE	% OF COARSE AGGREGATE	REACTION RIMS / GEL / FRACTURES	REMARKS
Biotite garnet gneiss	85 - 90	Tight fractures through and around aggregate particles.	Migmatites derived from sandstone, chert, iron formation and metasediments.
Other gneisses and volcanics	10 - 15	Same as above.	Same as above.

FINE AGGREGATE

Source	:	Pits at Fraser Creek and Bass Creek.				
% of total volume	:	40-45 %	**Visual estimate** [X]	**Point count** [ ]		
Material type	:	**Natural** [X]	**Manufactured** [ ]	**Mixture** [ ]	**Other** -	
Shape	:	**Rounded** [ ]	**Subrounded** [X]	**Subangular** [X]	**Angular** [ ]	
Distribution	:	**Even** [ ]	**Uneven** [X]	**Chaotic** [ ]		
Preferred orientation	:	**Present** [ ]	**Not observed** [X]			

cont.

CEMENT MATRIX

% of total volume :	15-20 %	Visual estimate [X]		Point count [ ]			
Appearance of broken surface :		Subtranslucent [ ]		Dull [X]		Chalky [ ]	
Colour :	Grey [X]	Light Grey [ ]	White [ ]	Brown [ ]		Other -	
Colour distribution :	Even [X]	Mottled [ ]		Gradational [ ]			
Bleeding :	Extensive [ ]	Minor [ ]		Not observed [X]			
Carbonation :	Surficial only [X]	Along fractures [ ]		Partial [ ]		Total [ ]	
Slag cement :	Observed [ ]	Not observed [X]					
Fly ash :	Observed [ ]	Not observed [X]					

VOIDS

% of total volume :	1-3 %	Visual estimate [X]		Point count [ ]			
Distribution :	Even [ ]	Uneven [X]		Clustered [ ]			
Shape :	Spherical [ ]	Nonspherical [ ]		Ellipsoidal [ ]		Irregular [X]	
Entrained air :	Air-entrained [ ]	Non-air-entrained [X]					
Interior lustre :	Dull [X]	Shining [ ]					
Interior condition :	Empty [X]	Lined [X]		Partly filled [X]		Totally filled [ ]	
% Voids with mineralization :	Most [ ]	About half [ ]		Few [X]		None [ ]	
Mineralization :	Alkali-silica gel [X]	Ettringite [ ]		Portlandite [X]		Calcium carbonate [ ]	

CRACKS

Amount : Extensive [ ] Occasional [X] None [ ]

Continuity and Distribution : Discontinuous and concentrated around coarse aggregate particles.

Orientation :	Vertical [ ]	Horizontal [ ]	Random [X]	
Location :	Through aggregate particles [X]		Around aggregate particles [X]	
Width (mm) :	Range 0.1 to 0.2	Average < 0.1		
% filled :	20-30 %			
Filling material :	Alkali-silica gel [X]	Ettringite [ ]	Portlandite [X]	
	Calcium carbonate [X]	Other -		
Associated with embedded items :	Yes [ ]	No [X]		

EMBEDDED ITEMS Yes [ ] No [X]

Description :
Condition : Clean [ ] Corroded [ ] Decayed [ ]
Size (mm) :
Location / Orientation :
Other :

GENERAL COMMENTS

Elongated coarse aggregate particles show a preferred orientation parallel to the concrete surface.

Approved by : Submitted by :

Distribution : Mr. P.K. Mukherjee, Mr. E.J. McColm, Mr. D.G. Wilkinson, Original to Mr. M.F. Everitt, Official Record

Report No : SN89-7-K

ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE

Project :	Pine Portage GS	**Job No.** :	42-113-581
Region :	Northwestern	**File No.** :	842.52 PIN
Area :	Thunder Bay	**Report No.** :	SN89-8-K
Structure :	Spillway Pier 5	**Date Issued** :	August 18, 1989

Sample Type : **Core** [X] **Cylinder** [ ] **Chunk** [ ]

Sample Description : Section 5-7 (interval 1600 mm - 1880 mm, nominal 85 mm diameter) taken from the upstream end. The concrete has undergone approximately 40 years of exposure in an environment of high relative humidity.

Sample Preparation : **Freshly broken surface** [ ] **Weathered surface** [ ] **Polished face** [X] **Thin Section** [X] / **No.** LTS 16

CONCRETE

Hit with hammer	:	**Ring** [X]		**Dull** [ ]		
Break with fingers	:	**Particles not dislodged** [X]		**Powdery** [ ]	**Friable** [ ]	
During sawing	:	**Clean cut** [X]		**Breaks easily** [ ]		
Cement / coarse aggregate bond	:	**Good** [X]		**Partial** [ ]	**Poor** [ ]	
Cement / fine aggregate bond	:	**Good** [X]		**Partial** [ ]	**Poor** [ ]	
Presence of honeycombing	:	**Not observed** [X]		**Minor** [ ]	**Extensive** [ ]	

COARSE AGGREGATE

Source	:	Bedrock from site excavations.			
% of total volume	:	30-35 %	**Visual estimate** [X]	**Point count** [ ]	
Material type	:	**Gravel** [ ]	**Quarried** [X]	**Mixture** [ ]	**Other -**
Shape	:	**Rounded** [ ]	**Partly crushed** [ ]	**100 % Crushed** [X]	
Distribution	:	**Even** [ ]	**Uneven** [X]	**Chaotic** [ ]	
Nominal size	:	28 (mm)			
Maximum size	:	28 (mm)			
Preferred orientation	:	**Present** [X]	**Not observed** [ ]		

LITHOLOGICAL TYPE	% OF COARSE AGGREGATE	REACTION RIMS / GEL / FRACTURES	REMARKS
Biotite garnet gneiss	80 - 90	Tight fracture through and around coarse aggregate particles.	Migmatites derived from sandstone, chert, iron formation and metasediments.
Other gneisses and volcanics	10 - 20	Same as above.	Same as above.

FINE AGGREGATE

Source	:	Pits at Fraser Creek and Bass Creek.				
% of total volume	:	35-40 %	**Visual estimate** [X]	**Point count** [ ]		
Material type	:	**Natural** [X]	**Manufactured** [ ]	**Mixture** [ ]	**Other -**	
Shape	:	**Rounded** [ ]	**Subrounded** [X]	**Subangular** [X]	**Angular** [ ]	
Distribution	:	**Even** [ ]	**Uneven** [X]	**Chaotic** [ ]		
Preferred orientation	:	**Present** [ ]	**Not observed** [X]			

cont.

CEMENT MATRIX

% of total volume :	20-25 %	Visual estimate [X]		Point count [ ]		
Appearance of broken surface :		Subtranslucent [ ]		Dull [X]	Chalky [ ]	
Colour :	Grey [X]	Light Grey [X]	White [ ]	Brown [ ]	Other -	
Colour distribution :	Even [ ]	Mottled [X]		Gradational [ ]		
Bleeding :	Extensive [ ]	Minor [X]		Not observed [ ]		
Carbonation :	Surficial only [X]	Along fractures [ ]		Partial [ ]	Total [ ]	
Slag cement :	Observed [ ]	Not observed [X]				
Fly ash :	Observed [ ]	Not observed [X]				

VOIDS

% of total volume :	3-5 %	Visual estimate [X]	Point count [ ]		
Distribution :	Even [ ]	Uneven [X]	Clustered [ ]		
Shape :	Spherical [ ]	Nonspherical [ ]	Ellipsoidal [ ]	Irregular [X]	
Entrained air :	Air-entrained [ ]	Non-air-entrained [X]			
Interior lustre :	Dull [X]	Shining [X]			
Interior condition :	Empty [X]	Lined [X]	Partly filled [ ]	Totally filled [ ]	
% Voids with mineralization :	Most [X]	About half [ ]	Few [ ]	None [ ]	
Mineralization :	Alkali-silica gel [X]	Ettringite [X]	Portlandite [ ]	Calcium carbonate [ ]	

CRACKS

Amount : Extensive [ ] Occasional [X] None [ ]

Continuity and Distribution : Discontinuous and unevenly distibuted.

Orientation :	Vertical [ ]	Horizontal [ ]	Random [X]	
Location :	Through aggregate particles [X]	Around aggregate particles [X]		
Width (mm) :	Range 0.1 to 0.2	Average < 0.1		
% filled :	10-20 %			
Filling material :	Alkali-silica gel [X]	Ettringite [ ]	Portlandite [X]	
	Calcium carbonate [ ]	Other -		
Associated with embedded items :	Yes [ ]	No [X]		

EMBEDDED ITEMS Yes [ ] No [X]

Description :
Condition : Clean [ ] Corroded [ ] Decayed [ ]
Size (mm) :
Location / Orientation :
Other :

GENERAL COMMENTS

Elongated coarse aggregate particles show a preferred orientation parallel to the concrete surface. Darkening of the cement paste around some aggregate particles indicates the presence of alkali-silica gel.

Approved by : Submitted by :

Distribution : Mr. P.K. Mukherjee, Mr. E.J. McColm, Mr. D.G. Wilkinson, Original to Mr. M.F. Everitt, Official Record

Report No : SN89-8-K